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AUTHOR	Capa, Yesim; Loadman, William E.
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ABSTRACT

The purpose of this study was to investigate the effect of a Rasch-based procedure to calibrate responses for funding applications. The data set included 112 proposals and 66 readers, who independently scored randomly assigned proposals using a scoring instrument. The data were analyzed using FACETS (Linacre, 1999). The analysis indicated that the instrument succeeded in separating proposals into four distinct strata of quality. The proposal quality measures were found to be trustworthy in terms of their accuracy and stability. The 17 items on the scoring instrument were functioning as intended with a reliability of 0.98. Readers were found to be internally consistent while using the instrument to assess the quality of the proposals. Decision makers could easily translate the findings provided by the analyses and rely on the precision of the estimates to make reliable and defensible funding decisions. (Contains 5 tables and 11 references.) (Author)

A RASCH MEASUREMENT EXAMPLE IN GRANT APPLICATION PROCESS

Yesim CAPA

The Ohio State University

William E. LOADMAN

The Ohio State University

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Abstract

The purpose of this study was to investigate the effect of a Rasch-based procedure to calibrate responses for funding applications. The data set included 112 proposals and 66 readers, which independently scored randomly assigned proposals using a scoring instrument. The data were analyzed using *Facets* (Linacre, 1999).

The analysis indicated that the instrument succeeded in separating proposals into four distinct strata of quality. The proposal quality measures were found to be trustworthy in terms of their accuracy and stability. The 17 items on the scoring instrument were functioning as intended with a reliability of .98. Readers were found to be internally consistent while using the instrument to assess the quality of the proposals. Finally, decision makers could easily translate the findings provided by the analyses and rely on the precision of the estimates to make reliable and defensible funding decisions.

A Rasch measurement example in grant application process

When complex assessment systems are used to allocate dollars for grants, based on a request for a proposal, decision makers need information that would help them to determine if all facets of the system of proposal review including the proposal reviewers (readers), the items, the proposals, and the rating scales are working as intended. It is important to simultaneously estimate the rated quality of the proposals, and the difficulty/ease of the items, and the severity/leniency of the readers. This could not be accomplished by a classical test theory approach. Utilizing the many-facet Rasch model allows for the simultaneous estimation of variations in the severity of judges, the item ease/difficulty, and the proposal quality. Thus, it eliminates or accounts for the differences in the measurement model beyond reader ratings of the reviewed proposal (Linacre, Wright, & Lunz, 1990).

Another advantage provided by the facet model is that its use does not necessitate each proposal to be reviewed by every reader on all of the items. Wright and Stone (1979) stated that the only requirement is a network to link every parameter to the other parameter by means of ratings. This network allows all measures to be placed on a common continuum.

The context for this study was a state initiative announced through a request for a proposal (RFP) initiative for competitively based funding support. The applicants (school districts) developed and submitted a written proposal seeking support for their proposal initiative. Multiple awards were anticipated in the announced RFP.

The purpose of this study was to investigate the effect of Rasch-based procedures to calibrate responses for funding applications. More specifically, it was aimed to estimate three sources of variability within the rating system: applications, items, and readers. The data collected in this study were analyzed by using Linacre's (1999) FACETS computer program.

In this paper, a brief theory related to the many-facet Rasch measurement will be presented to better inform the audience about the analyses that were performed. Then, statistical analyses and the terminology used by *Facets* will be explained in the context of present study.

The final section of the report will include subsections of the result part. First, the map will be examined because it allows us to see all facets of the analysis within a single frame of reference. Next, several questions will be addressed regarding the sources of variability: How well did applications calibrate? How well did readers calibrate? How well did items calibrate? Finally, a recommendation will be made to help decision makers use the information in the administration of the grant process.

Many – Facet Rasch Model

The many-facet analysis used in this study describes the probability that a specific application (n) rated by a specific reader (j) will be rated in a particular category (k) on a specific item (i). Here is the mathematical form of the three-facet Rasch model that shows the relationships among these facets in terms of a logistics odds ratio:

$$\text{Log}\left(\frac{P_{nijk}}{P_{nijk-1}}\right) = B_n - D_i - C_j - F_k$$

where

P_{nijk} is the probability of application n being rated by reader j on item i with a rating of k,

P_{nijk-1} is the probability of application n being rated by reader j on item i with a rating of k-1,

B_n is the quality of the application n,

D_i is the difficulty of item i,

C_j is the severity of reader j,

F_k is the difficulty (F) of category k of the rating scale (Linacre, 1994).

In this study, the measurement model specifies that a common rating scale category structure applies across all items and for all readers; in other words F_k is constant across items and readers. It must be noted that there is no mathematical limit on the number of facets included in the model; however, most applications do not go beyond two or three facets in addition to the item and person (or application) facet (Smith, 1996).

The psychometric model, presented above in the mathematical form, includes three facets – applications, readers, and items. The *Facets* program uses the ratings that readers give on all items to estimate measures for each element of each facet. For each application, the measure is an estimate of that application's quality. The larger the measure, the better the application. For each reader, the measure is an estimate of the degree of severity that each reader exercised while evaluating the quality of the application. The larger the measure, the more severe the reader. For each item, the measure is an estimate of the difficulty of the item. The larger the measure, the more difficult it is for an application to obtain high ratings on that item. All of the measures that Facet produces are in the same linear unit of measure which is in logits, or log-odds units. Thus, the comparison within and between the facets of the analysis is straightforward and more importantly consistent (Myford & Wolfe, 2000).

Moreover, along with each measure the *Facets* program produces a standard error, which gives information about the precision of the logit estimate, and fit statistics, which provides information about how well the data fit the expectations of the measurement model. Fit statistics are presented by two measures: infit and outfit mean squares (Linacre, 1999b). Mean square, which is a chi-square statistic with an expectation of 1 and range of 0 to infinity, is based on the ratio of observed error variance to modeled error variance. The *Outfit* statistics are unweighted mean square residuals that are specifically sensitive to the outliers. On the other hand, the *Infit* statistics weight each standardized residual by its variance and are more sensitive to unexpected responses near the point where decisions are made. A standardized value of the mean square statistics is also provided by the *Facets*. Different researchers have been using different cutoffs for identifying misfitting items, applications, or readers. Even some have been using standardized residuals. Wright, Linacre, Gustafson, and Martin (1994) reported that there are "no hard-and fast rules" for these measures and the decision depends on the purpose of research and the researcher (p.370). For example, high-stakes tests would tolerate less noise than low-stakes tests. For the purpose of this study, mean square values between 0.5 and 1.8 were investigated. The standardized values weren't used because they are affected by sample size.

It must be emphasized that in order to employ a Facets Model, the data must meet two requirements. First, the data must be approximately unidimensional, i.e., most of the items should produce data along the same underlying construct. Second, the data must show local independence, i.e., the probability of responding to one item should not affect the response to another item (Smith, 1996; Wright, 1996). These assumptions are common in all item response theory models.

Method

The data set included 112 proposals (including a calibration application) and 66 readers. The calibration application, which was scored by all readers, was not an actual application but a proposal used to assist in the calibration of all readers. Readers underwent a training program, in which they are informed about the rating instrument and process, perspectives on reading and scoring applications, and data analysis. At least three readers were assigned randomly to evaluate the quality of the proposals. Readers independently scored each assigned proposal using the scoring instrument. The trio of readers for each application was unique to each application as the three member composition of each trio was consistently rotated.

Instrument

A reader scoring instrument, generated on the basis of the content required in the RFP, consisted of 18 items of which 17 of them are used for final calibrated score. The 17 items include six-point rating scale: 1 is given when no evidence is provided; 4 is given when the item is addressed, and evidence is detailed with few examples of quality; and 6 is used when item is addressed, exceptionally well-developed and high-quality examples are presented. The last item assesses the overall quality of the application and includes six-point scale where 1 is the poor application and 6 is the exceptional application.

Assumption check

The unidimensionality assumption is likely to be satisfied because of the characteristics of the instrument. The correlation matrix among items (See Table 1) also indicates that all items are significantly correlated; this could be accepted as a sign that the instrument has a single dimension. Moreover, it should be noted: Wright suggested that violating this assumption would not cause significant difficulty. According to Hambleton, Swaminathan, & Rogers (1991), this assumption cannot be strictly met because of several external factors. What is required for the unidimensionality assumption to be met adequately by a set of test data is the presence of a "dominant" factor.

Insert Table 1

In order to not to violate the assumption of local independence, the item 18, assessing the overall quality of the proposal, was excluded from the *Facets* analysis.

Missing Data

In *Facets* analysis, there is considerable allowance for missing data. Each parameter could be estimated from the subset of observations. Linacre (1994) stated that there is no need for imputation of values in order to handle missing data. Analysis will produce stable estimates unless there is tremendous amount of missing data or all observations are in the same extreme category.

When inspecting data by application, it appears that there are only three cases in which three out of 17 responses are missing. This corresponds to approximately 18% of the data for that individual application, which could be ignored as a problem.

Data Analysis

The data were analyzed by using the FACETS program (Linacre, 1999a), a Rasch-based computer program based on an extension of Wright and Masters' rating scale model. The output from the FACETS analysis provided information about the calibrated quality of each proposal, the utility of each item, and the scoring behavior of each reader.

Results

Before interpreting the results, the subset connection should be controlled. In this analysis, the subset connection was satisfied, which indicates that the estimated parameters of three facets can be placed on a common scale with the same origin and that there is no identification problem in the estimation process.

In this study, there are three facets: 112 applications, 66 readers, and 17 evaluation items. There were at least three readers per application. The Facets can accommodate unequal number of readers per application. After producing the iteration report (4 PROX and 24 UCON Iterations), it provided the list of unexpected responses – 32 unexpected residuals including 6 from the calibration application, which forms only .004% of the total responses (Table 2).

Insert Table 2

The map shown as Figure 1 displays all facets of the analysis in one figure; for that reason, it is powerful to examine this map first before looking at the fits statistics for the facets (Myford & Wolfe, 2000). The scale of the map is in "logits" for all facets, which forms an equal-interval scale and enables comparison of the results.

Insert Figure 1

The **first column** in the map depicts the logit scale. The **second column** indicates the estimated quality of applications. Higher quality applications appear at the top of the column, while lower quality applications appear at the lower end of the column. Each star represents two applications, and a dot represents one application. These measures of estimate show a fairly negatively skewed distribution with three very low quality applications.

The **third column** displays the level of leniency – severity of the readers. In this column, more severe readers appear at the higher end of the column, and more lenient readers appear at the lower end of the column. The reader severity measures show a symmetric distribution with a narrower range than the application measures. The reader severity measures were calibrated around the mean (0), with 32 out of 66 readers on the severe side (logit higher than 0) and 28 out of 66 readers on the lenient side (logit less than 0).

The **fourth column** shows the 17 items in terms of their relative ease – difficulty. Items appearing higher in the column are more difficult for applications to receive high ratings than the items appearing lower in the column. Item 17 appears to be the most difficult item in the instrument; the other items are relatively easier items.

From this point, the paper addresses itself to the detailed description of the results of application analysis, the reader analysis, and the item analysis.

Application analysis

Application measures are presented in ascending order of quality in Table 3.

Insert Table 3

Applications #96, #22, and #19 are the higher quality applications, whereas application #61 and #69 are the lower quality applications. The following information is presented in this table: observed score, observed count (the number of ratings), observed average (average for the ratings), and the fair average (average adjusted for reader severity), the logit measure and standard error, and the fit information including the infit and outfit mean square statistics for each application. By using the criteria previously established (logit score higher than 1.8 or lower than 0.5), when both infit and outfit statistics are examined, none of the applications present an area of concern. At the bottom of the table, overall statistics are presented. For this run, the separation reliability is .94, indicating that the differences among application measures are mainly due to the actual differences rather than the measurement error. The applications can also be separated into 4 distinct strata of quality (separation index = 4.11). The Root Mean

Square Error (RMSE) of 0.11 indicates a relatively low error in application measures.

Unlike the standard error of measurement in classical test theory, *Facets* provides a separate estimate of standard error for each application. The standard error of measurement indicates how much we would expect an application's quality estimate to change if different readers and/or different items were used. The average standard error of measurement for the applications is 0.11.

Reader analysis

Reader measures of severity/leniency are presented in Table 4.

Insert Table 4

Readers #1061 and #1013 are relatively more severe, and the readers #1038 and #1026 are relatively more lenient. By using the previously established criteria when both infit and outfit statistics are examined, 3 out of 66 readers had either high (>1.8) or low (<0.5) infit and outfit statistics. The readers that have low infit/outfit statistics are: #1031 and #1041. Their ratings tend to be "muted." The low scores are of less concern, which are tending to show a flat line pattern and little variation. In some cases, one might question whether the readers rate each item independently or whether a halo effect or centrality effect may be operating (Myford &Wolfe, 2000).

The reader with high infit/outfit statistics is: #1066. When we check the unexpected response table (Table 2), it appears that this reader rated the quality of application #22 unexpectedly low on items #8, #9, #11, and #13, while the application's rating is higher on average. Moreover, this reader tended to rate leniently overall, therefore unexpectedly low rating is surprising. This reader could be removed from the calibration of the application or provided with additional training for future use as a reader. The ratings of the readers with high infit measures tend to be "noisy," indicating that their rating shows more variation than expected in their ratings. Generally, it is recommended that readers with high infit/outfit statistics be trained for better quality of rating (Myford &Wolfe, 2000).

At the bottom of the table, overall statistics are presented. For this run, the separation reliability for readers is .91, indicating that the analysis is fairly reliable in separating readers into three different levels of severity and leniency (separation = 3.10). The RMSE score of .09 indicates that reader error is fairly low. To investigate whether the readers differ in their severity with which they rate applications, the fixed chi-square test is used. The chi-square of 874.6 with 65 degrees of freedom is significant (alpha=.01). This implies that readers are not considered equally severe/lenient after allowing for measurement error. This degree of leniency – severity is used to adjust the calibrated score for each application.

Item Analysis

Item measures are presented in Table 5. Items #17 and #15 are difficult to endorse, and items #3, #6, and #14 are relatively easier items in the instrument. These findings are also presented in Figure 1.

Insert Table 5

The *Facets* also provides a number of indications of the magnitude of the differences among elements of this facet, which is the difficulty/easiness of the items. These are: RMSE, Reliability, Separation Index, Fixed and Random Chi-square, Infit and Outfit statistics.

The RMSE score of 0.04 indicates that item error is very low. The reliability of items is very high (.98), and this is preferable for most studies. We could also interpret reliability such that the analysis is reliably separating items into approximately seven levels of difficulty (separation=6.68). Fixed chi-square tests the null hypothesis that all of the elements of item facet are equal. The fixed chi-square of 819.2 with degrees of freedom 16 is significant at the alpha .01, showing that the null hypothesis is rejected. Therefore, it could be concluded that items are not of equal difficulty/easiness. Random chi-square tests the hypothesis: "Can this set of elements be regarded as a random sample from a normal distribution?" The random chi-square of 16.0 with degrees of freedom 15 is not significant at the alpha .05. Thus, it could be implied that items could be regarded as a random sample from a normal distribution.

Using the same criteria to investigate the infit and outfit statistics (lower than 0.5 indicates muting; higher than 1.8 indicates noise), it appears that infit/outfit mean square of item #15 and #17 are higher than 1.8. That shows these items were not compatible with the quality estimates of the applications, and scores for these items may not be stable. The infit statistics of item #16 is also high (1.7), although not higher than the established criteria. This might occur because all of them appear as the last items. The readers might not have enough time to rate them adequately. Moreover, when we check the unexpected response table (Table 2), 14 out of 32 unexpected responses include item #15, #16, and particularly #17. The next time, the ordering of the questions might be changed to see if it happens again or the item might be modified for clarity. Because item #17 also appears as the most difficult item to endorse, this item could be revised or removed from the instrument.

Conclusion

By utilizing the *Facets* analysis, we obtained specific information about how each element of each facet (i.e., each application, reader, and item) was performing. Results from our study indicated that the test succeeded in separating proposals (with a reliability of .94) into four distinct strata of quality. The distribution of the proposal quality measures was very similar in range to the distribution of reader severity measures. The *Facets* reports overall measure of accuracy and stability of proposal quality measures that is similar to the concept of standard error of measurement in classical test theory. The average standard error of measurement for the proposals was 0.11, which indicates fairly stable estimates of proposal quality if different readers or items were used. None of the proposals had infit and outfit mean-square indices either lower than 0.5 or higher than 1.8, which indicates the consistency shown in evaluating the quality of applications across items and across readers.

For items, the reliability was very high (.98), which is preferable in research studies. The infit and outfit mean-square indices for 17 items ranged from 0.6 to 2.1. Two of the items had fit statistics higher than 1.8, indicating noise or excess variation. Both of these items appear as the last items. Overall, it could be implied that rating on the items could be meaningfully combined to produce a single composite score to reflect the quality of the application.

The *Facets* also yielded a measure of the degree of severity each reader exercised while evaluating the proposals. The reader severity measures ranged from -0.66 logits to 0.66 logits, a 1.32 logit spread. The resulting chi-square value for readers was 945.1 with 65 degrees of freedom. This implied that readers could not be considered as equally severe/lenient after allowing for the measurement error. In addition, reader fit statistics provided evidence that readers were internally consistent while using the instrument to assess the quality of the application.

In general, it would be concluded that all of the elements of the study including applications, readers, and items were functioning as intended. The Rasch measurement has an effective role to play in analysis and reporting of the data collected for the purpose of grant application review. The decision makers could easily use the findings provided by the analysis and rely on the accuracy of the estimates considering that the severity of the readers are also taken into account in the measurement model. Moreover, implications could be drawn for better rating process.

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Table 1

Intercorrelations for Items

	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17
I1	0.48	0.45	0.46	0.37	0.39	0.47	0.33	0.37	0.35	0.26	0.31	0.46	0.33	0.28	0.30	0.15
I2		0.51	0.50	0.58	0.50	0.60	0.41	0.39	0.38	0.35	0.29	0.36	0.33	0.22	0.29	0.18
I3			0.67	0.57	0.54	0.62	0.39	0.43	0.44	0.41	0.37	0.46	0.36	0.23	0.33	0.26
I4				0.50	0.52	0.52	0.38	0.40	0.38	0.31	0.38	0.41	0.32	0.31	0.35	0.25
I5					0.60	0.57	0.37	0.43	0.44	0.42	0.38	0.38	0.34	0.12	0.22	0.21
I6						0.58	0.40	0.44	0.44	0.40	0.36	0.37	0.34	0.26	0.28	0.20
I7							0.48	0.47	0.45	0.42	0.43	0.39	0.42	0.25	0.34	0.21
I8								0.34	0.41	0.42	0.36	0.36	0.34	0.30	0.29	0.17
I9									0.61	0.47	0.52	0.51	0.38	0.23	0.35	0.19
I10										0.61	0.52	0.43	0.44	0.13	0.28	0.18
I11											0.53	0.44	0.39	0.18	0.28	0.22
I12												0.50	0.44	0.24	0.40	0.27
I13													0.56	0.28	0.36	0.22
I14														0.24	0.27	0.24
I15															0.54	0.25
I16																0.29

Note. All correlations are significant at the .05 significance level

Table 2

Unexpected Responses (32 residuals sorted by order in data).

Cat	Step	Exp.	Resd	StRes	Num	app	Num	read	Nu	it
2	2	5.0	-3.0	-3	11	11	1039	1039	1	1
1	1	4.7	-3.7	-3	11	11	1039	1039	15	15
1	1	4.9	-3.9	-3	11	11	1039	1039	16	16
3	3	5.5	-2.5	-3	19	19	1064	1064	2	2
3	3	5.5	-2.5	-3	19	19	1064	1064	5	5
2	2	5.5	-3.5	-4	22	22	1066	1066	8	8
3	3	5.5	-2.5	-3	22	22	1066	1066	9	9
3	3	5.4	-2.4	-3	22	22	1066	1066	11	11
3	3	5.5	-2.5	-3	22	22	1066	1066	13	13
1	1	4.8	-3.8	-3	25	25	1016	1016	3	3
1	1	4.7	-3.7	-3	34	34	1047	1047	13	13
2	2	5.1	-3.1	-3	47	47	1024	1024	14	14
1	1	4.6	-3.6	-3	48	48	1013	1013	12	12
1	1	4.7	-3.7	-3	49	49	1059	1059	16	16
2	2	5.1	-3.1	-3	53	53	1002	1002	12	12
6	6	2.2	3.8	3	55	55	1011	1011	17	17
4	4	1.5	2.5	3	69	69	1021	1021	12	12
1	1	4.6	-3.6	-3	87	87	1059	1059	16	16
6	6	2.1	3.9	3	88	88	1052	1052	17	17
6	6	2.1	3.9	3	92	92	1016	1016	17	17
6	6	2.0	4.0	3	94	94	1058	1058	17	17
1	1	4.6	-3.6	-3	96	96	1013	1013	8	8
1	1	5.1	-4.1	-4	106	106	1038	1038	17	17
5	5	1.8	3.2	3	108	108	1040	1040	15	15
4	4	1.5	2.5	3	108	108	1040	1040	17	17
1	1	4.6	-3.6	-3	110	110	1068	1068	16	16
2	2	5.0	-3.0	-3	5000	5000	1033	1033	5	5
1	1	4.8	-3.8	-3	5000	5000	1038	1038	15	15
1	1	4.9	-3.9	-3	5000	5000	1048	1048	14	14
2	2	5.1	-3.1	-3	5000	5000	1064	1064	14	14
1	1	4.6	-3.6	-3	5000	5000	1069	1069	16	16
2	2	5.1	-3.1	-3	5000	5000	1008	1008	14	14
Cat	Step	Exp.	Resd	StRes	Num	app	Num	read	Nu	it

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Vertical = (1*,2*,3A) Yardstick (columns,lines,low,high)= 0,10,-2,2
-----------------------------------------------------
|Measr|+app     |-readers|-items                |S.1  |
-----------------------------------------------------
+   2 +         +        +                      +(6)  +
|     |         |        |                      |     |
|     | High    | Severe |  Difficult           |     |
|     | score   |        |                      |     |
|     |         |        |                      | --- |
|     |         |        |                      |     |
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|     | *.      |        |                      | 5   |
|     | ***.    |        |                      |     |
|     | **      |        | 17                   |     |
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|     | *****.  | **     | 15                   |     |
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|     | ***     | ****.  | 2   5   9   12  13   | --- |
|     | **      | *.     | 4   7                |     |
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|     | .       |        |                      |     |
|     |         |        |                      |     |
|     |         |        |                      |     |
|     | .       |        |                      | --- |
|     |         |        |                      |     |
|     | Low     | Lenient|   Easy               |     |
|     | score   |        |                      |     |
+  -2 +         +        +                      +(1)  +
-----------------------------------------------------
|Measr| * = 2   | * = 2  |-items                |S.1  |
-----------------------------------------------------
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Figure 1

Variable Map of Application Measures, Reader Measures, and Item Calibrations

Table 3

Summary Statistics for Application Measures Ranked by the Logit Scores

Obsvd Score	Obsvd Count	Obsvd Average	Fair-M Avrage	Measure	Model S.E.	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd	Num	app
85	51	1.7	1.49	-1.46	.15	0.6	-1	0.6	-1	61	61
95	51	1.9	1.79	-1.10	.14	1.1	0	1.1	0	69	69
111	51	2.2	2.34	-.68	.12	1.1	0	1.3	1	108	108
158	50	3.2	2.43	-.63	.10	1.2	1	1.3	1	94	94
174	68	2.6	2.46	-.61	.09	0.6	-3	0.6	-3	6	6
190	68	2.8	2.63	-.52	.09	0.7	-1	0.7	-2	5	5
151	51	3.0	2.74	-.46	.10	1.1	0	1.2	0	64	64
134	51	2.6	2.77	-.44	.11	0.6	-2	0.6	-2	71	71
156	51	3.1	2.86	-.40	.10	0.8	-1	0.8	-1	109	109
161	51	3.2	2.90	-.38	.10	0.6	-2	0.6	-2	105	105
137	51	2.7	3.02	-.32	.11	0.6	-2	0.6	-2	44	44
160	51	3.1	3.05	-.30	.10	1.2	1	1.2	1	73	73
237	68	3.5	3.19	-.23	.09	0.6	-3	0.6	-3	27	27
193	51	3.8	3.27	-.19	.10	1.3	1	1.2	1	40	40
197	49	4.0	3.33	-.17	.11	0.6	-2	0.6	-2	111	111
159	50	3.2	3.35	-.16	.10	0.6	-3	0.6	-3	60	60
187	51	3.7	3.37	-.15	.10	0.9	0	0.9	0	74	74
177	51	3.5	3.43	-.12	.10	0.8	-1	0.8	-1	78	78
252	68	3.7	3.47	-.10	.09	0.8	-1	0.8	-1	4	4
190	51	3.7	3.48	-.09	.10	0.9	0	0.9	0	101	101
199	51	3.9	3.51	-.08	.11	1.0	0	1.0	0	56	56
195	51	3.8	3.56	-.05	.10	1.0	0	1.0	0	77	77
248	68	3.6	3.68	.01	.09	1.0	0	0.9	0	41	41
196	51	3.8	3.71	.02	.11	0.7	-1	0.7	-2	42	42
206	51	4.0	3.70	.02	.11	1.6	2	1.5	2	62	62
183	50	3.7	3.70	.02	.10	1.0	0	1.0	0	88	88
253	68	3.7	3.74	.04	.09	1.3	1	1.3	2	7	7
238	68	3.5	3.75	.04	.09	0.8	-1	0.8	-1	9	9
203	51	4.0	3.75	.04	.11	0.9	0	0.8	-1	76	76
201	50	4.0	3.75	.04	.11	0.9	0	0.9	0	85	85
187	51	3.7	3.74	.04	.10	1.1	0	1.2	1	89	89
205	51	4.0	3.75	.04	.11	0.8	-1	0.7	-1	95	95
168	51	3.3	3.77	.05	.10	0.8	-1	0.8	-1	102	102
163	51	3.2	3.76	.05	.10	0.5	-4	0.5	-4	107	107
183	51	3.6	3.78	.06	.10	0.9	0	0.9	0	58	58
202	49	4.1	3.79	.06	.11	1.2	0	1.1	0	75	75
270	68	4.0	3.81	.07	.09	1.0	0	0.9	0	18	18
234	68	3.4	3.80	.07	.09	0.9	0	0.8	-1	37	37
183	51	3.6	3.81	.07	.10	0.9	0	0.9	0	66	66
211	51	4.1	3.80	.07	.11	1.5	2	1.5	2	100	100
246	68	3.6	3.82	.08	.09	1.0	0	1.0	0	33	33
203	51	4.0	3.83	.08	.11	1.0	0	0.9	0	72	72
209	51	4.1	3.85	.09	.11	1.7	3	1.6	2	55	55
184	51	3.6	3.96	.15	.10	1.1	0	1.1	0	92	92
194	51	3.8	3.95	.15	.11	0.8	-1	0.7	-1	93	93
192	51	3.8	4.00	.17	.10	1.3	1	1.3	1	99	99
245	68	3.6	4.05	.20	.09	0.7	-2	0.7	-2	13	13
216	51	4.2	4.05	.20	.11	1.4	1	1.3	1	84	84
280	67	4.2	4.06	.21	.10	1.0	0	0.9	0	35	35
233	65	3.6	4.09	.22	.09	1.0	0	1.0	0	54	54
215	51	4.2	4.09	.23	.11	0.9	0	0.9	0	98	98
294	67	4.4	4.13	.25	.10	1.6	3	1.5	2	34	34
270	67	4.0	4.16	.26	.09	1.3	1	1.3	1	23	23
272	68	4.0	4.15	.26	.09	0.9	0	0.9	0	31	31

Table 3 (continued)

Obsvd Score	Obsvd Count	Obsvd Average	Fair-M Avrage	Measure	Model S.E.	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd	Num	app
336	84	4.0	4.16	.26	.09	0.9	0	0.9	0	46	46
209	51	4.1	4.20	.29	.11	0.8	-1	0.8	-1	70	70
217	51	4.3	4.22	.30	.11	0.7	-1	0.6	-2	90	90
233	51	4.6	4.27	.33	.12	0.9	0	0.9	0	65	65
230	51	4.5	4.27	.33	.12	0.9	0	0.8	-1	81	81
294	68	4.3	4.29	.34	.10	0.9	0	0.9	0	1	1
297	67	4.4	4.31	.35	.10	1.2	0	1.1	0	36	36
200	51	3.9	4.33	.36	.11	1.2	0	1.1	0	59	59
268	67	4.0	4.34	.37	.09	0.8	-1	0.8	-1	12	12
273	68	4.0	4.34	.37	.09	0.8	-1	0.8	-1	15	15
383	85	4.5	4.34	.37	.09	1.0	0	1.0	0	50	50
281	68	4.1	4.37	.39	.10	1.2	1	1.2	1	38	38
4654	**1081**	**4.3**	**4.38**	**.40**	**.02**	**1.0**	**0**	**1.0**	**0**	**5000**	**5000**
280	68	4.1	4.40	.41	.09	0.9	0	0.8	0	3	3
305	68	4.5	4.40	.41	.10	0.8	-1	0.7	-1	52	52
265	68	3.9	4.40	.41	.09	0.9	0	0.9	0	79	79
221	51	4.3	4.43	.43	.12	0.9	0	0.9	0	91	91
294	68	4.3	4.49	.47	.10	1.4	1	1.2	1	17	17
276	68	4.1	4.53	.49	.09	0.9	0	0.9	0	29	29
281	68	4.1	4.54	.50	.10	1.0	0	0.9	0	20	20
222	49	4.5	4.53	.50	.12	1.2	1	1.1	0	51	51
219	51	4.3	4.55	.51	.11	0.7	-1	0.6	-2	103	103
303	68	4.5	4.57	.52	.10	0.9	0	0.8	0	82	82
242	51	4.7	4.57	.53	.13	1.2	0	1.0	0	43	43
287	68	4.2	4.59	.54	.10	1.1	0	1.1	0	14	14
223	51	4.4	4.59	.54	.11	1.0	0	0.9	0	16	16
378	85	4.4	4.60	.55	.09	0.9	0	0.9	0	28	28
305	67	4.6	4.62	.56	.11	1.3	1	1.4	1	11	11
223	50	4.5	4.62	.56	.12	1.0	0	0.9	0	67	67
316	68	4.6	4.66	.59	.11	1.0	0	0.9	0	8	8
382	85	4.5	4.67	.60	.09	1.2	1	1.1	0	26	26
326	68	4.8	4.67	.60	.11	1.1	0	1.1	0	47	47
225	50	4.5	4.66	.60	.12	1.3	1	1.2	0	86	86
328	68	4.8	4.72	.64	.11	1.2	1	1.2	0	2	2
249	51	4.9	4.72	.64	.14	0.9	0	0.8	-1	104	104
389	85	4.6	4.73	.65	.10	1.3	1	1.2	0	25	25
237	50	4.7	4.74	.65	.13	1.2	0	1.2	0	87	87
323	68	4.8	4.77	.68	.11	1.1	0	1.0	0	49	49
232	51	4.5	4.79	.70	.12	1.0	0	1.0	0	80	80
232	49	4.7	4.83	.73	.13	1.4	1	1.2	0	97	97
321	67	4.8	4.88	.77	.11	1.0	0	0.9	0	24	24
239	49	4.9	4.89	.78	.14	1.4	1	1.3	0	83	83
254	51	5.0	4.90	.80	.14	1.3	1	1.2	0	53	53
325	68	4.8	4.92	.81	.11	1.1	0	1.1	0	21	21
239	50	4.8	4.92	.81	.13	0.8	0	0.9	0	68	68
252	51	4.9	4.92	.82	.14	0.7	-1	0.6	-1	45	45
329	68	4.8	4.96	.85	.11	1.3	1	1.1	0	30	30
340	68	5.0	4.96	.85	.12	1.1	0	1.0	0	39	39
250	51	4.9	5.03	.92	.14	1.0	0	0.9	0	110	110
355	68	5.2	5.05	.95	.14	1.0	0	0.8	0	10	10
332	68	4.9	5.07	.96	.12	1.0	0	0.8	-1	32	32
224	49	4.6	5.07	.96	.12	1.0	0	0.9	0	63	63
339	68	5.0	5.14	1.04	.12	1.3	1	1.0	0	48	48
250	51	4.9	5.14	1.04	.14	1.2	0	0.9	0	57	57
252	50	5.0	5.14	1.05	.15	1.8	2	1.6	1	106	106
342	68	5.0	5.18	1.10	.13	1.1	0	1.1	0	19	19
350	68	5.1	5.19	1.11	.13	1.4	1	1.7	2	22	22

Table 3 (continued)

Obsvd Score	Obsvd Count	Obsvd Average	Fair-M Avrage	Measure	Model S.E.	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd	Num app
252	51	4.9	5.22	1.15	.14	1.6	2	1.5	1	96 96
280.1	68.0	4.1	4.10	.28	.11	1.0	-0.1	1.0	-0.3	Mean
419.9	96.7	0.7	0.75	.46	.02	0.3	1.5	0.2	1.4	S.D.

RMSE (Model) .11 Adj S.D. .45 Separation 4.11 Reliability .94
Fixed (all same) chi-square: 1761.2 d.f.: 111 significance: .00
Random (normal) chi-square: 109.4 d.f.: 110 significance: .50

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Table 4

Summary Statistics for Reader Measures Ranked by the Number of Readers

Obsvd Score	Obsvd Count	Obsvd Average	Fair-M Avrage	Measure	Model S.E.	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd	Num	readers
416	102	4.1	4.38	-.12	.08	1.0	0	1.0	0	1002	1002
78	17	4.6	4.23	-.03	.21	0.6	-1	0.6	-1	1003	1003
635	136	4.7	4.65	-.31	.08	1.2	1	1.1	0	1006	1006
430	119	3.6	4.73	-.37	.07	1.0	0	1.0	0	1007	1007
382	85	4.5	4.71	-.35	.09	1.4	2	1.4	2	1008	1008
583	153	3.8	3.79	.21	.06	0.6	-4	0.6	-4	1009	1009
257	68	3.8	3.84	.19	.09	0.6	-3	0.6	-3	1010	1010
320	85	3.8	3.98	.11	.08	1.5	3	1.5	3	1011	1011
340	84	4.0	3.15	.53	.09	1.3	2	1.4	2	1013	1013
483	119	4.1	3.81	.21	.07	1.0	0	1.0	0	1014	1014
553	118	4.7	4.57	-.25	.08	1.0	0	0.9	0	1015	1015
457	119	3.8	3.74	.24	.07	1.2	2	1.3	2	1016	1016
523	115	4.5	4.37	-.12	.08	1.4	2	1.2	1	1017	1017
265	68	3.9	3.93	.14	.09	0.6	-3	0.5	-3	1018	1018
606	136	4.5	4.17	.01	.07	1.1	0	1.0	0	1019	1019
526	136	3.9	3.74	.24	.07	0.8	-1	0.8	-1	1020	1020
78	34	2.3	3.46	.38	.15	0.9	0	1.0	0	1021	1021
631	153	4.1	4.45	-.17	.06	0.8	-2	0.8	-1	1022	1022
432	100	4.3	4.41	-.14	.08	0.8	-1	0.8	-1	1024	1024
668	170	3.9	3.97	.12	.06	0.8	-2	0.8	-2	1025	1025
394	85	4.6	4.91	-.53	.10	0.6	-2	0.6	-2	1026	1026
390	102	3.8	3.87	.17	.07	0.6	-4	0.6	-3	1029	1029
592	153	3.9	4.02	.09	.06	0.7	-2	0.7	-3	1030	1030
339	**102**	**3.3**	**3.44**	**.39**	**.08**	**0.5**	**-4**	**0.5**	**-4**	**1031**	**1031**
623	136	4.6	4.63	-.29	.08	1.0	0	0.8	-1	1032	1032
470	102	4.6	4.75	-.39	.09	1.4	2	1.4	2	1033	1033
492	114	4.3	4.09	.05	.08	1.6	3	1.5	3	1034	1034
530	118	4.5	4.47	-.18	.08	1.3	2	1.2	1	1035	1035
596	136	4.4	4.64	-.30	.07	0.8	-1	0.8	-1	1036	1036
616	152	4.1	4.22	-.02	.07	1.0	0	0.9	0	1037	1037
785	153	5.1	5.03	-.64	.09	1.2	1	1.0	0	1038	1038
638	135	4.7	4.79	-.42	.09	1.6	3	1.5	2	1039	1039
647	151	4.3	4.11	.04	.07	1.1	0	1.1	0	1040	1040
480	**135**	**3.6**	**4.22**	**-.03**	**.06**	**0.5**	**-6**	**0.5**	**-6**	**1041**	**1041**
374	85	4.4	4.04	.08	.09	1.0	0	0.9	0	1045	1045
364	85	4.3	4.35	-.10	.09	0.6	-3	0.6	-3	1046	1046
590	135	4.4	4.64	-.30	.07	0.9	-1	0.8	-1	1047	1047
514	118	4.4	4.34	-.10	.08	1.2	1	1.2	1	1048	1048
677	202	3.4	3.18	.52	.05	0.8	-2	0.8	-2	1049	1049
442	119	3.7	3.28	.47	.07	0.8	-1	0.8	-1	1050	1050
456	119	3.8	3.55	.34	.07	0.8	-1	0.8	-1	1051	1051
382	102	3.7	3.98	.11	.07	1.2	1	1.2	1	1052	1052
473	102	4.6	4.40	-.13	.09	0.9	0	0.8	-1	1053	1053
545	152	3.6	3.91	.15	.06	0.9	0	0.9	0	1054	1054
578	170	3.4	3.74	.24	.06	1.0	0	0.9	0	1056	1056
469	119	3.9	4.56	-.24	.08	1.1	1	1.1	0	1057	1057
689	151	4.6	4.81	-.44	.07	1.1	0	0.9	0	1058	1058
444	100	4.4	4.37	-.11	.08	1.2	1	1.2	1	1059	1059
584	135	4.3	3.95	.13	.07	1.0	0	0.9	0	1060	1060
466	136	3.4	2.93	.64	.06	0.8	-1	0.8	-1	1061	1061
473	115	4.1	4.30	-.07	.07	1.3	2	1.3	2	1062	1062
366	85	4.3	3.84	.19	.09	0.9	0	0.9	0	1063	1063
319	67	4.8	4.62	-.28	.11	1.6	2	1.6	2	1064	1064
494	**101**	**4.9**	**4.89**	**-.50**	**.10**	**2.0**	**4**	**2.1**	**4**	**1066**	**1066**
575	153	3.8	3.65	.28	.06	1.2	2	1.2	2	1067	1067

Table 4 (continued)

Obsvd Score	Obsvd Count	Obsvd Average	Fair-M Avrage	Measure	Model S.E.	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd	Num	readers
358	85	4.2	3.89	.16	.09	1.2	1	1.2	1	1068	1068
608	136	4.5	4.71	-.35	.07	1.6	3	1.5	3	1069	1069
533	135	3.9	3.90	.16	.07	1.2	1	1.2	1	1070	1070
390	101	3.9	3.51	.35	.07	1.0	0	1.0	0	1071	1071
418	101	4.1	3.99	.11	.08	1.2	1	1.1	0	1072	1072
579	153	3.8	3.99	.11	.07	1.1	0	1.0	0	1073	1073
181	51	3.5	3.33	.44	.10	0.8	-1	0.8	-1	1074	1074
703	170	4.1	4.21	-.02	.06	0.9	0	0.8	-1	1075	1075
579	118	4.9	4.63	-.29	.09	1.2	1	1.0	0	1076	1076
77	17	4.5	4.39	-.13	.21	0.6	-1	0.6	-1	1077	1077
413	102	4.0	3.94	.14	.08	0.7	-2	0.7	-2	1078	1078
475.3	115.3	4.1	4.14	.00	.08	1.0	-0.1	1.0	-0.4	Mean	
147.0	35.2	0.5	0.47	.28	.03	0.3	2.3	0.3	2.2	S.D.	

RMSE (Model) .09 Adj S.D. .27 Separation 3.10 Reliability .91
Fixed (all same) chi-square: 874.6 d.f.: 65 significance: .00
Random (normal) chi-square: 65.5 d.f.: 64 significance: .43

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Table 5

Summary Statistics for Items (arranged by the number of items)

Obsvd Score	Obsvd Count	Obsvd Average	Fair-M Avrage	Measure	Model S.E.	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd	Nu items
1842	450	4.1	4.13	.03	.04	0.9	-1	0.9	0	1 1
1953	450	4.3	4.40	-.13	.04	0.7	-5	0.7	-4	2 2
2047	450	4.5	4.62	-.28	.04	0.7	-5	0.7	-4	3 3
1991	450	4.4	4.49	-.19	.04	0.7	-5	0.7	-5	4 4
1947	449	4.3	4.39	-.13	.04	0.8	-3	0.9	-2	5 5
2046	449	4.6	4.63	-.29	.04	0.6	-5	0.7	-5	6 6
1995	450	4.4	4.50	-.20	.04	0.6	-6	0.7	-5	7 7
1792	447	4.0	4.03	.08	.04	1.0	0	1.0	0	8 8
1896	444	4.3	4.33	-.09	.04	0.7	-5	0.7	-5	9 9
1768	440	4.0	4.05	.08	.04	0.7	-5	0.7	-4	10 10
1675	448	3.7	3.73	.25	.04	0.9	-2	0.9	-1	11 11
1892	448	4.2	4.27	-.05	.04	0.8	-3	0.8	-2	12 12
1917	448	4.3	4.33	-.09	.04	0.8	-2	0.9	-2	13 13
2015	445	4.5	4.60	-.27	.04	0.9	-1	1.0	0	14 14
1581	**447**	**3.5**	**3.49**	**.36**	**.04**	**2.0**	**9**	**1.9**	**9**	**15 15**
1722	448	3.8	3.84	.19	.04	1.7	9	1.7	8	16 16
1289	**448**	**2.9**	**2.73**	**.74**	**.04**	**2.1**	**9**	**2.0**	**9**	**17 17**
1845.2	447.7	4.1	4.15	.00	.04	1.0	-1.5	1.0	-1.0	Mean
190.6	2.6	0.4	0.47	.26	.00	0.4	5.2	0.4	5.0	S.D.

RMSE (Model) .04 Adj S.D. .26 Separation 6.68 Reliability .98
Fixed (all same) chi-square: 819.2 d.f.: 16 significance: .00
Random (normal) chi-square: 16.0 d.f.: 15 significance: .38

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Author(s): Yesim CAPA & William E. LOADMAN

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